

## WHAT IS CLAIMED IS:

1. A cylindrical bonding structure on a chip having one or more bonding pads thereon, comprising:

a conductive cylinder on the bonding pad of the chip; and

5 a solder block on the conductive cylinder, wherein the solder block is made from a material having a melting point lower than the conductive cylinder.

2. The structure of claim 1, wherein the bonding pad is the original bonding pad on the chip.

3. The structure of claim 1, wherein the chip further includes a redistribution circuit  
10 layer and the bonding pad is a pad on the redistribution circuit layer.

4. The structure of claim 1, wherein the solder block is a solder ball.

5. The structure of claim 1, wherein the solder block is a cylindrical solder cap.

6. The structure of claim 5, wherein the cylindrical solder cap has an outer diameter smaller than the conductive cylinder.

15 7. The structure of claim 1, wherein material forming the conductive cylinder is selected from a group consisting of tin, lead, copper, gold, silver, zinc, bismuth, magnesium, antimony, indium and an alloy of the aforementioned metals.

8. The structure of claim 1, wherein material forming the solder block is selected from a group consisting of tin, lead, copper, gold, silver, zinc, bismuth, magnesium,  
20 antimony, indium and an alloy of the aforementioned metals.

9. The structure of claim 1, wherein the structure further includes a ball contact metallic layer between the conductive cylinder and the bonding pad.

10. The structure of claim 1, wherein the structure further includes a transition layer between the conductive cylinder and the solder block.

11. The structure of claim 10, wherein the transition layer has at least one conductive layer.

5 12. A method of forming one or more cylindrical bonding structures over a silicon wafer having an active surface and at least one bonding pad on the active surface, comprising the steps of:

forming a ball contact metallic layer over the entire active surface of the silicon wafer, including the bonding pads;

10 forming a patterned mask layer over the ball contact metallic layer, wherein the first mask layer has at least one opening that corresponds in position to the bonding pad and exposes a portion of the ball contact metallic layer;

15 depositing conductive material into the opening to form a conductive cylinder over the ball contact metallic layer, wherein the conductive material only partially fills the opening;

depositing solder material into the remaining space of the opening to form at least one cylindrical solder cap on the upper surface of the conductive cylinder, wherein the solder material has a melting point lower than the conductive cylinder material; and

20 removing the mask layer and the ball contact metallic layer outside the conductive cylinder such that the remaining ball contact metallic layer, the conductive cylinder and the cylindrical solder cap together form the cylindrical bonding structure.

13. The method of claim 12, wherein the bonding pad is an original bonding pad on the wafer.

14. The method of claim 12, wherein the wafer further includes a redistribution circuit layer and the bonding pad is a pad on the redistribution circuit layer.

15. The method of claim 12, wherein after removing the mask layer and a portion of the ball contact metallic layer, further includes conducting a reflow operation to transform the cylindrical solder cap into a solder block.

16. The method of claim 12, wherein the step of depositing conductive material into the opening includes conducting an electroplating operation.

17. The method of claim 12, wherein the step of depositing solder material into the opening includes conducting an electroplating or a printing operation.

18. The method of claim 12, wherein after forming the conductive cylinder but before forming the cylindrical solder cap, further includes forming a transition layer over the upper surface of the conductive cylinder so that the cylindrical solder cap is formed over the transition layer.

19. The method of claim 18, wherein the transition layer has at least one conductive layer.

20. The method of claim 12, wherein material forming the conductive cylinder is selected from a group consisting of tin, lead, copper, gold, silver, zinc, bismuth, magnesium, antimony, indium and an alloy of the aforementioned metals.

21. The method of claim 12, wherein material forming the solder block is selected from a group consisting of tin, lead, copper, gold, silver, zinc, bismuth, magnesium, antimony, indium and an alloy of the aforementioned metals.

22. The method of claim 12, wherein material forming the mask layer includes photoresist.

23. The method of claim 12, wherein the step of forming the patterned mask layer includes forming a photoresist layer over the ball contact metallic layer and patterning the photoresist layer.

24. The method of claim 23, wherein the step of patterning the photoresist layer  
5 includes conducting a photo-exposure and developing the exposed photoresist layer.

25. A method of forming one or more cylindrical bonding structures over a silicon wafer having an active surface and at least one bonding pad on the active surface, comprising the steps of:

forming a ball contact metallic layer over the entire active surface of the  
10 silicon wafer, including the bonding pads;

forming a patterned mask layer over the ball contact metallic layer, wherein the mask layer has at least one opening that corresponds in position to the bonding pad and exposes a portion of the ball contact metallic layer;

depositing conductive material into the opening to form a conductive cylinder  
15 over the ball contact metallic layer, wherein the conductive material only partially fills the opening;

removing the mask layer and the ball contact metallic layer outside the conductive cylinder; and

attaching a solder ball onto the upper surface of the conductive cylinder such  
20 that the remaining ball contact metallic layer, the conductive cylinder and the solder ball together form the cylindrical bonding structure.

26. The method of claim 25, wherein the bonding pad is the original bonding pad on the wafer.

27. The method of claim 25, wherein the wafer further has a redistribution circuit layer and the bonding pads are pads on the redistribution circuit layer.

28. The method of claim 25, wherein the step of depositing conductive material into the opening includes conducting an electroplating operation.

5 29. The method of claim 25, wherein after forming the conductive cylinder but before attaching the solder ball, further includes forming a transition layer on the upper surface of the conductive cylinder so that the solder ball is attached to the transition layer.

30. The method of claim 29, wherein the transition layer has at least one conductive layer.

10 31. The method of claim 25, wherein material forming the conductive cylinder is selected from a group consisting of tin, lead, copper, gold, silver, zinc, bismuth, magnesium, antimony, indium and an alloy of the aforementioned metals.

15 32. The method of claim 25, wherein material forming the solder ball is selected from a group consisting of tin, lead, copper, gold, silver, zinc, bismuth, magnesium, antimony, indium and an alloy of the aforementioned metals.

33. The method of claim 25, wherein material forming the mask layer includes photoresist.

20 34. The method of claim 25, wherein the step of forming the patterned mask layer includes forming a photoresist layer over the ball contact metallic layer and patterning the photoresist layer.

35. The method of claim 34, wherein the step of patterning the photoresist layer includes conducting a photo-exposure and developing the exposed photoresist layer.

36. A cylindrical bonding structure on a silicon chip such that the structure may flip over and connect with a substrate, wherein the chip has at least one bonding pad and the substrate has a substrate surface having a patterned solder mask and at least one junction pad thereon, and the solder mask layer has at least an opening that exposes the junction pad, the  
5 cylindrical bonding structure comprising:

a conductive cylinder on the bonding pad of the chip; and

a cylindrical solder cap on the conductive cylinder, wherein the cylindrical solder cap has an outer diameter smaller than the diameter of the opening in the solder mask and a length greater than the depth of the opening, and the solder material has a melting point  
10 lower than the conductive cylinder material.

37. The structure of claim 36, wherein the bonding pad is the original bonding pad on the chip.

38. The structure of claim 36, wherein the chip further includes a redistribution circuit layer and the bonding pad is a pad on the redistribution circuit layer.

15 39. The structure of claim 36, wherein material forming the conductive cylinder is selected from a group consisting of tin, lead, copper, gold, silver, zinc, bismuth, magnesium, antimony, indium and an alloy of the aforementioned metals.

40. The structure of claim 36, wherein material forming the cylindrical solder cap is selected from a group consisting of tin, lead, copper, gold, silver, zinc, bismuth, magnesium,  
20 antimony, indium and an alloy of the aforementioned metals.

41. The structure of claim 36, wherein the structure further includes a ball contact metallic layer between the conductive cylinder and the bonding pad.

42. The structure of claim 36, wherein the structure further includes a transition layer between the conductive cylinder and the cylindrical solder cap.

43. The structure of claim 42, wherein the transition layer has at least one conductive layer.

5        44. A method of forming one or more cylindrical bonding structures over a silicon wafer having an active surface and at least one bonding pad on the active surface, comprising the steps of:

forming a ball contact metallic layer over the entire active surface of the silicon wafer, including the bonding pads;

10        forming a patterned first mask layer over the ball contact metallic layer, wherein the first mask layer has at least one opening that corresponds in position to the bonding pad and exposes a portion of the ball contact metallic layer;

depositing conductive material into the opening to form a conductive cylinder over the ball contact metallic layer;

15        forming a patterned second mask layer over the first mask layer, wherein the second mask layer has at least one opening than exposes a portion of the conductive cylinder;

depositing solder material into the opening to form a cylindrical solder cap over the conductive cylinder, wherein the solder material has a melting point lower than the conductive cylinder material; and

20        removing the first mask layer, the second mask layer and the ball contact metallic layer outside the conductive cylinder such that the remaining ball contact metallic layer, the conductive cylinder and the cylindrical solder cap together form the cylindrical bonding structure.

45. The method of claim 44, wherein the bonding pad is the original bonding pad on the wafer.

46. The method of claim 44, wherein the wafer further has a redistribution circuit layer and the bonding pads are pads on the redistribution circuit layer.

5 47. The method of claim 44, wherein the step of depositing conductive material into the first mask layer opening includes conducting an electroplating operation.

48. The method of claim 44, wherein the step of depositing solder material into the second mask layer opening includes conducting an electroplating operation.

10 49. The method of claim 44, wherein after forming the conductive cylinder but before the cylindrical solder cap, further includes forming a transition layer on the upper surface of the conductive cylinder so that the cylindrical solder cap is formed over the transition layer.

50. The method of claim 49, wherein the transition layer has at least one conductive layer.

15 51. The method of claim 44, wherein material forming the conductive cylinder is selected from a group consisting of tin, lead, copper, gold, silver, zinc, bismuth, magnesium, antimony, indium and an alloy of the aforementioned metals.

52. The method of claim 44, wherein material forming the solder material is selected from a group consisting of tin, lead, copper, gold, silver, zinc, bismuth, magnesium, antimony, indium and an alloy of the aforementioned metals.

20 53. The method of claim 44, wherein material forming the first mask layer includes photoresist.



54. The method of claim 44, wherein the step of forming the patterned first mask layer includes forming a photoresist layer over the ball contact metallic layer and patterning the photoresist layer.

55. The method of claim 54, wherein the step of patterning the photoresist layer  
5 includes conducting a photo-exposure and developing the exposed photoresist layer.

56. The method of claim 44, wherein material forming the second mask layer includes photoresist.

57. The method of claim 44, wherein the step of forming the patterned second mask layer includes forming a photoresist layer over the first mask layer and patterning the  
10 photoresist layer.

58. The method of claim 57, wherein the step of patterning the photoresist layer includes conducting a photo-exposure and developing the exposed photoresist layer.

59. A method of connecting a chip to a substrate to form a flip-chip package, wherein the chip has an active surface having at least a bonding pad thereon, the substrate has a  
15 substrate surface having a patterned solder mask and at least one junction pad thereon, and the solder mask has at least one opening that exposes the junction pad, the method comprising the steps of:

forming a cylindrical bonding structure on the bonding pad of the chip,  
wherein the cylindrical bonding structure comprises a conductive cylinder and a solder block,  
20 the bottom surface of the conductive cylinder is on top of the bonding pad and the bottom surface of the solder block is on the upper surface of the conductive cylinder, and the solder block has a melting point lower than the conductive cylinder;

flipping over the active surface of the chip to face the substrate surface of the substrate such that the upper surface of the solder block contacts the junction pad; and conducting a reflow process to melt the solder block material so that the conductive cylinder and the junction pad are joined together.

5           60. The method of claim 59, wherein the bonding pad is the original bonding pad on the chip.

61. The method of claim 59, wherein the wafer further has a redistribution circuit layer and the bonding pads are pads on the redistribution circuit layer.

62. The method of claim 59, wherein material forming the conductive cylinder is  
10           selected from a group consisting of tin, lead, copper, gold, silver, zinc, bismuth, magnesium, antimony, indium and an alloy of the aforementioned metals.

63. The method of claim 59, wherein material forming the solder block is selected from a group consisting of tin, lead, copper, gold, silver, zinc, bismuth, magnesium, antimony, indium and an alloy of the aforementioned metals.

15           64. The method of claim 59, wherein the solder block is a cylindrical solder cap.

65. The method of claim 64, wherein the cylindrical solder cap has an outer diameter smaller than the opening diameter on the solder mask.

66. The method of claim 65, wherein the cylindrical solder cap has a length greater than the depth of the opening on the solder mask.

20           67. The method of claim 59, wherein the cylindrical bonding structure further includes a ball contact metallic layer between the conductive cylinder and the bonding pad on the chip.

68. The method of claim 59, wherein the cylindrical bonding structure further includes a transition layer between the conductive cylinder and the solder block.

69. The method of claim 68, wherein the transition layer has at least a conductive layer.